Behavior Patterns, Origin of Problems and Solutions Regarding Hysteresis Phenomena in Complex Battery Systems

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Published in:
Hysteresis: Types, Applications and Behavior Patterns in Complex Systems

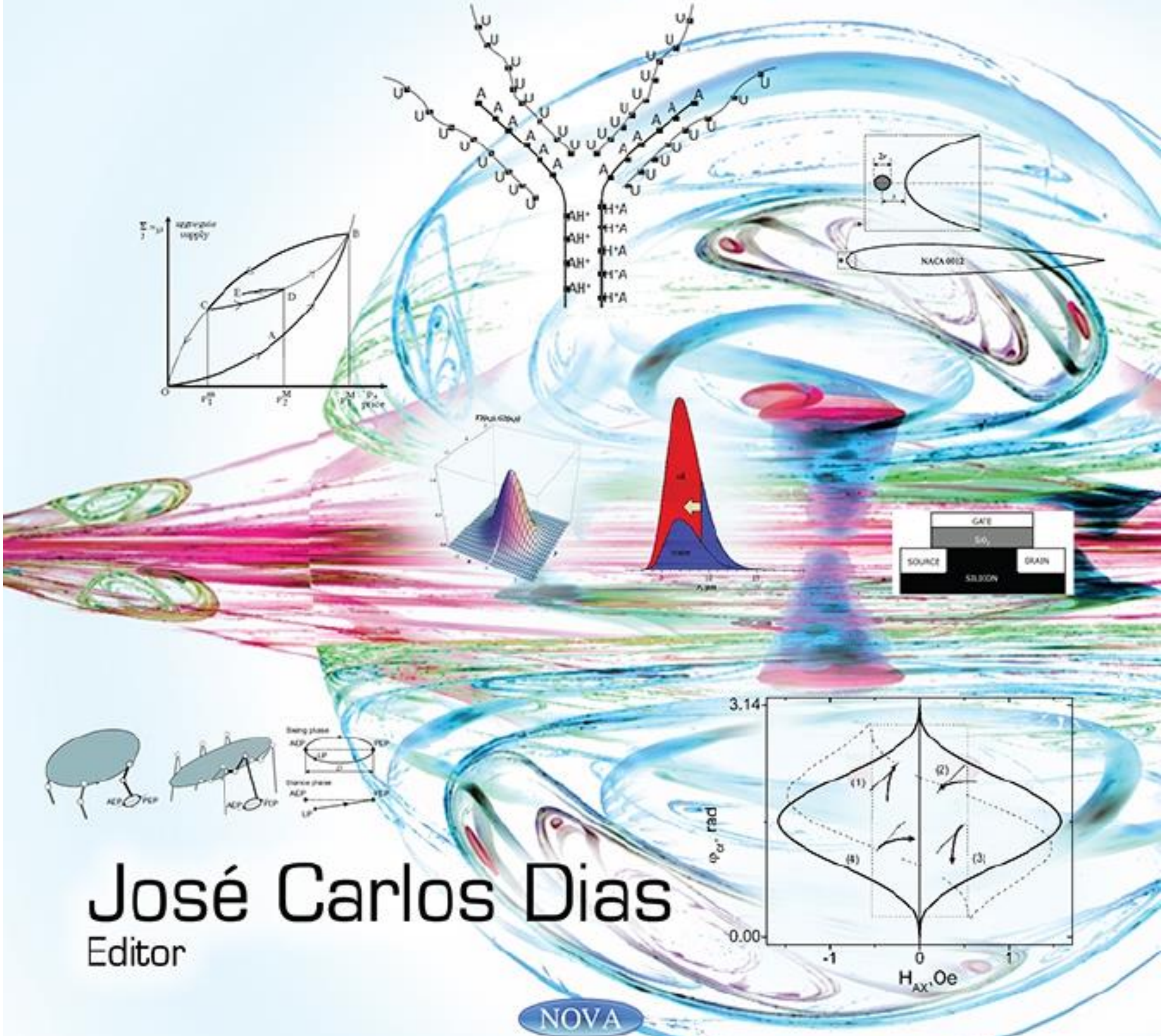
Publication date:
2014

Document Version
Early version, also known as pre-print

MATERIALS SCIENCE AND TECHNOLOGIES

Hysteresis

Types, Applications and Behavior Patterns in Complex Systems



José Carlos Dias
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NOVA

Chapter 10

BEHAVIOR PATTERNS, ORIGIN OF PROBLEMS AND SOLUTIONS REGARDING HYSTERESIS PHENOMENA IN COMPLEX BATTERY SYSTEMS

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ABSTRACT

One of the common phenomena for most of the battery cell chemistries is hysteresis. Since an open circuit voltage (OCV) path is not identical for the charge and discharge of the battery cell at different states of charge (SoC) level, the battery cell show the hysteresis effect. Usually, the OCV i.e. voltage with zero current after previous charge is higher than the OCV after discharge at the same SoC level. It embodies the hysteresis of the battery cell. The OCV is principally subjected to previous operating condition and cannot be taken as self-regulating from the operating history. Therefore, an accurate knowledge of the hysteresis of OCV is vital for various applications and battery models. This is because currently Battery Management Systems (BMS) use the well-defined OCV-SoC representative curve for SoC estimation and power prediction. Particularly lithium-ion batteries with iron-phosphate cathode material show a complex OCV behavior including a hysteresis that is dependent on the previous operation i.e. the previous state - charging or discharging. The extent of drawbacks related to hysteresis varies on specific cell chemistry. Those batteries are more prone to catastrophes due to failures to estimate the correct SoC or energy content of the battery consequently limiting operation life of the battery pack. Therefore, novel and more cutting-edge hysteresis management strategies are required to be able to prevent securely the energy storage system from ever facing these critical circumstances. In case of the exchanging between the charging and discharging curves (due to exposure of charge and discharge pulse) makes the SoC estimation problematic since switching from the OCV leads to sudden changes in the output of SoC that physically is not consistent for a battery cell. In this chapter, the characteristics of OCV in function of relaxation times for different Li-ion chemistries are presented. Moreover, a novel hysteresis compensation structure is introduced based on Kalman filter and statistical error function. These combinations are able to meet the high requirements of estimating accurate SoC using open circuit voltage. In addition, the issues of safety and reliability are going to be increased for the integration of the newly established compensation scheme for the hysteresis phenomenon. A hysteresis compensation framework is elaborated in the subsequent sections of this chapter.

Keywords: Battery Management System; Hysteresis compensation; Open Circuit Voltage; State of Charge; Lithium ion batteries.

INTRODUCTION

For consumer applications such as laptops, smartphones, hybrid electric vehicles (HEVs) and electric vehicles (EVs), $LiCoO_2$ based cathode material is currently the preferred choice but the future trend is shifting on mixed oxide cathodes ($LiNi_xCo_yAl_zO_2$ (NCA) and $LiNi_xMn_yCo_zO_2$ (NMC)) or $LiFePO_4$ owing to sufficient power density and

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